Angular Distribution Measurements of Gamma-Rays from the $^{22}\text{Ne}(p, \gamma)^{23}\text{Na}$ Reaction

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Angular distribution measurements of gamma-rays from the $^{22}\text{Ne}(p, \gamma)^{23}\text{Na}$ reaction on the $E_p=897, 1006, 1091$ and 1278 keV resonances have been made. Spin and parity assignments for several bound states are presented together with multipole mixing ratios for transitions from resonance and bound states. The level at 6617 keV ($7/2^+$) is proposed to be a member of the rotational band based on the Nilsson orbit $5\pi\varphi = 5/2^+$.

1. Introduction

The present investigation is a continuation of earlier $^{23}\text{Na}$ research performed in this laboratory in which the lifetimes of the bound states $E_\gamma<4$ MeV in $^{23}\text{Na}$ were measured by the Doppler shift attenuation method$^1$ and the gamma decays of the $(p, \gamma)$ resonances in the range of $E_p=400-2600$ keV were investigated$^2,^3$. The purpose of the present work was to gain further experimental information on quantum numbers and multipole mixing ratios by measuring angular distributions of gamma-rays from the $^{22}\text{Ne}(p, \gamma)^{23}\text{Na}$ reaction.

Earlier investigations concerning the spins and parities of bound states and multipole mixing ratios of various transition in $^{23}\text{Na}$ have been performed by Poletti et al.$^4,^5$ through the $^{26}\text{Mg}(p, \alpha\gamma)^{23}\text{Na}$ and $^{24}\text{Mg}(t, \alpha\gamma)^{23}\text{Na}$ reactions, da Silva et al.$^6$ through the $^{24}\text{Mg}(t, \alpha\gamma)^{23}\text{Na}$ reaction, and Maier et al.$^7$ through the $^{23}\text{Na}(p, p')^{23}\text{Na}$ reaction.

Braben et al.$^8$ and Wernbom-Selin and Arnell$^9$ have earlier performed angular distribution measurements through the $(p, \gamma)$ reaction using NaI(Tl) techniques.

2. Experimental Procedure

The experiments were performed with the Helsinki 3 MV van de Graaff accelerator. The proton beam was deflected through a 90° analysing magnet, the field of which was measured by the NMR method.

Targets were prepared with the electromagnetic isotope separator at the University of Helsinki. Separations were performed by implanting 50 keV $^{22}$Ne ions into a tantalum backing.

The angular distribution measurements were made at five angles, $\theta = 0°, 30°, 45°, 60°$ and $90°$, where $\theta$ is the angle between the proton beam and the detector axis. Gamma-rays were detected with a Philips 38 cm$^3$ Ge(Li) detector (FWHM 4.2 keV at 2.61 MeV) coupled to a 4096 channel Nuclear Data analyzer. The distance from the target spot to the detector was 5 cm. Solid angle corrections were obtained by extrapolation from the values reported by Camp and van Lehn$^{10}$.

A PDP-15 computer was employed in the analysis of the angular distribution measurements.

3. Angular Distribution Measurements

The angular distribution measurements were made on $E_p = 897, 1006, 1091$ and 1278 keV resonances. The gamma decay schemes of these resonances and branching ratios of the transitions from the resonance and bound states have been presented in our earlier paper$^2$.

The measured angular distributions can be expressed in terms of Legendre polynomials $P_i(\cos \theta)$:

$$W(\theta) = 1 + a_2 P_2(\cos \theta) + a_4 P_4(\cos \theta).$$

The experimental values of $a_2$ and $a_4$ obtained from least-squares fits are presented in Table 1. In Fig. 1 we display some angular distributions from our measurements.

Further analysis to obtain the possible spin values of the excited states and to determine gamma-ray multipole mixing ratios $\delta$ was carried out using a $\chi^2$-test. An illustration of the analysis performed for the 3678 keV state is presented in Fig. 2. The theoretical $W(\theta)$-functions were calculated with the aid of the tabulations of Yamazaki$^{11}$. In Table 2 the multipole mixing ratios $\delta$ of the primary gamma-rays measured in this investigation are presented.

A summary of the $\delta$-values of the secondary gamma-rays obtained in the present investigation is shown in Table 3. Corresponding values from two other investigations$^5, 6$ have been included for comparison.